CH_2OH. Both theories account for most of the hitherto known reactions of the glucoses, hence the matter has remained an open question. Drs. Fischer and Tafel, however, consider that their synthesis from acroleïn, which is itself an aldehyde, points to the probability of the former hypothesis being the correct one. The action of baryta water upon the dibromide evidently causes a simple exchange of bromine for hydroxyl, and the first product of the reaction is almost as certainly glycerine aldehyde, $CH_2OH—CHOH—CHO$. This latter substance, however, appears to polymerize at once under the influence of the baryta water into sugar, two molecules of glycerine aldehyde uniting to form a molecule of glucose.

In consideration of the fact of its derivation from acroleïn, the name acrose has been applied to the sugar which has been, with so much skill and steady determination, synthetically formed and isolated; and there can be no doubt that this name will stand as a memento of the progress made in organic chemistry during the year 1887.

A. E. TUTTON.

MODERN VIEWS OF ELECTRICITY.[1]

PART II.—CURRENT ELECTRICITY (*continued*).

IV.

Electrical Inertia.

RETURNING now to the general case of conduction, without regard to the special manner of it, we must notice that, if a current of electricity is anything of the nature of a material flow, there would probably be a certain amount of inertia connected with it, so that to start a current with a finite force would take a little time; and the stoppage of a current would also have either to be gradual or else violent. It is well known that if water is stagnant in a pipe it cannot be quite suddenly set in motion; and again, if it be in motion, it can only be suddenly stopped by the exercise of very considerable force, which jars and sometimes bursts the pipe. This impetus of running water is utilized in the water-ram. It must naturally occur, therefore, to ask whether any analogous phenomena are experienced with electricity; and the answer is, they certainly are. A current does not start instantaneously: it takes a certain time—often very short—to rise to its full strength; and when started it tends to persist, so that if its circuit be suddenly broken, it refuses to stop quite suddenly, and bursts through the introduced insulating partition with violence and heat. It is this ram or impetus of the electric current which causes the spark seen on breaking a circuit; and the more sudden the breakage the more violent is the spark apt to be.

The two effects—the delay at making circuit, and the momentum at breaking circuit—used to be called "extra-current" effects, but they are now more commonly spoken of as manifestations of "self-induction."

We shall understand them better directly; meanwhile they appear to be direct consequences of the inertia of electricity; and certainly if electricity *were* a fluid possessing inertia it would behave to a superficial observer just in this way.

But if an electric current really possessed inertia, as a stream of water does, it would exhibit itself not only by these effects but also mechanically. A conducting coil delicately suspended might experience a rotary kick every time a current was started or stopped in it; and if a steady current were maintained in such a coil it should behave like a top or gyrostat, and resist any force tending to deflect its plane.

Clerk Maxwell has carefully looked for this latter form of momentum effect, and found none. One may say, in fact, that nothing like momentum has yet been observed in an electric current by any *mechanical* mode of examination. A coil or whirl of electricity does not behave in the least like a top.

Does this prove that a current has no momentum? By no means necessarily so. It might be taken as suggesting that an electric current consists really of two equal flows in contrary directions, so that mechanically they neutralize one another completely, while electrically—*i.e.* in the phenomena of self-induction or extra-current—they add their effects. Or it may mean merely that the momentum is too minute to be so observed. Or, again, the whole thing—the appearance of inertia in some experiments and the absence of it in others—may have to be explained in some altogether less simple manner, to which we will proceed to lead up.

Condition of the Medium near a Circuit.

So far we have considered the flow of electricity as a phenomenon occurring solely inside conductors; just as the flow of water is a phenomenon occurring solely inside pipes. But a number of remarkable facts are known which completely negative this view of the matter. Something is no doubt passing along conductors when a current flows, but the disturbance is not *confined* to the conductor; on the contrary, it spreads more or less through all surrounding space.

The facts which prove this have necessarily no hydraulic analogue but must be treated *suorum generum*, and they are as follows:—

(1) A compass needle anywhere near an electric current is permanently deflected so long as the current lasts.

(2) Two electric currents attract or repel one another, according as they are in the same or opposite directions.

(3) A circuit in which a current is flowing tends to enlarge itself so as to inclose the greatest possible area.

(4) A circuit conveying a current in a magnetic field tends either to enlarge or to shrink or to turn half round according to the aspect it presents to the field.

(5) Conductors in the neighbourhood of an electric circuit experience momentary electric disturbances every time the current is started or stopped or varied in strength.

(6) The same thing happens even with a steady current if the distance between it and a conductor is made to vary.

(7) The effects of self-induction, or extra-currents, can be almost abolished by twisting the covered wire conveying the current closely on itself, or even by laying the direct and return wire side by side; whereas they may be intensified by making the circuit inclose a large area, more by coiling it up tightly into close coil, and still more by putting a piece of iron inside the coil so formed.

Nothing like any of these effects is observable with currents of water; and they prove that the phenomena of the current, so far from being confined to the wire, spread out into space and affect bodies at a considerable distance.

Nearly all this class of phenomena were discovered by Ampère and by Faraday, and were called by the latter "current-induction." According to his view the dielectric medium round a conducting circuit is strained, and subject to stresses, just as is the same medium round an electrically charged body. The one is called an electrostatic strain, the other an electro-magnetic or electro-kinetic strain.

But whereas electrostatic phenomena occur *solely* in the medium—conductors being mere breaks in it, interrupters of its continuity, at whose surface charge-effects occur but whose substance is completely screened from disturbance—that is not the case with electro-kinetic phenomena. It would be just as erroneous to conceive electro-kinetic phenomena as occurring solely in the insulating medium as it would be to think of them as occurring solely in the conducting wires. The fact is, they occur in both—not only at the surface of the wires like electrostatic effects, but all through their substance. This is proved by the fact that conductivity increases in simple proportion with sectional area; it is also proved by every part of a conductor getting hot; and it is further proved in the case of liquids by their decomposition.

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[1] Continued from vol. xxxvi. p. 585.

But the equally manifest facts of current attraction and current induction prove that the effect of the current is felt throughout the surrounding medium as well, and that its intensity depends on the nature of that medium; we are thus wholly prevented from ascribing the phenomenon of self-induction or extra-current to simple and straightforward inertia of electricity in a wire like that of water in a pipe.

We are thus brought face to face with another suggestion to account for these effects, viz. this: Since the molecules of a dielectric are inseparably connected with electricity, and move with it, it is possible that electricity itself has no inertia at all, but that the inertia of the atoms of the displaced dielectric confer upon it the appearance of inertia. Certainly they do sometimes confer upon it this appearance, as we see in the oscillatory discharge of a Leyden jar. For a displaced thing to overshoot its mean position and oscillate till it has expended all its energy, is a proceeding eminently characteristic of inertia; and so, perhaps, the phenomena of self-induction are similarly, though not so simply, explicable.

Further consideration of this difficult part of the subject is however best postponed to Part III.

Energy of the Current.

I have now called attention to the fact that the whole region surrounding a circuit is a field of force in which many of the most important properties of the current (the magnetic, to wit) manifest themselves. But directly we begin thus to attend to the whole space, and not only to the wires and battery, a very curious question arises. Are we to regard the current in a conductor as propelled by some sort of end-thrust, like water or air driven through a pipe by a piston or a fan, or are we to think of it as propelled by side forces, a sort of lateral drag, like water driven along a trough by a blast of air or by the vanes of paddle-wheels dipping into it? Or, again, referring to the cord models, Figs. 5, 6, and 13, were we right in picturing the driving force of the battery as located and applied where shown in the diagrams, or ought we to have schemed some method for communicating the power of the battery by means of belts or other mechanism to a great number of points of the circuit?

Prof. Poynting has shown that, on the principles developed by Maxwell, the latter of these alternatives, though apparently the more complicated, is the true one; and he has calculated the actual paths by which the energy is transmitted from the battery to the various points of a circuit, for certain cases.

We must learn, then, to distinguish between the flow of *electricity* and the flow of electric *energy*: they do not occur along the same paths. Hydraulic analogies, at least hydraulic analogies of a simple kind, break down here. When hydraulic power or steam power is conveyed along pipes, the fluid and its energy travel together. Work is done at one end of the tube in forcing in more water, and this is propagated along the tube and reappears at the distant end as the work of the piston. But in electricity it is not so. Electric energy is not to be regarded as pumped in at one end of a conducting wire, and as exuding in equal quantities at the other. The *electricity* does indeed travel thus—whatever the travel of electricity may ultimately be found to mean—but the energy does not. The battery emits its energy, not to the wire direct, but to the surrounding medium; this is disturbed and strained, and propagates the strain on from point to point till it reaches the wire and is dissipated. This, Prof. Poynting would say, is the function of the wire: it is to dissipate the energy crowding into it from the medium, which else would take up a static state of strain and cease to transmit any more. It is by the continuous dissipation of the medium's energy into heat that continuous propagation is rendered possible.

The energy of a dynamo does not therefore travel to a distant motor through the wires, but through the air. The energy of an Atlantic cable battery does not travel to America through the wire strands, but through the insulating sheath. This is a singular and apparently paradoxical view, yet it appears to be well founded.

Think of a tram-car drawn by an underground rope, like those in the streets of Chicago or Hampstead Hill. A contact piece of iron protrudes from the bottom of the car and grips the moving rope, which is thus enabled to propel the car. How does the energy of the distant stationary engine reach the car? *Viâ* the rope and the iron connector, undoubtedly. They both have to be strong, and are liable to be broken by the transmitted stress.

Next, think of an electric tram-car driven by means of a current taken up from an underground conductor, like that of Mr. Holroyd Smith at Manchester, or at the late Inventions Exhibition. A contact piece of wire rope protrudes from the bottom of the car and drags a little truck along the conductor, which is thus enabled to supply electricity to the electro-magnetic motor geared to the wheels. How does the energy of the distant dynamo reach the car in this case? *Not viâ* the wire connector; not even *viâ* the underground conductor. It travels from the distant dynamo through the general insulating medium between cable and earth, some little enters the conductor and is dissipated, but the great bulk flows on and converges upon the motor in the car, which is thus propelled. All the energy of the conducting wire is dissipated and lost as heat: it is the energy of the insulating medium which is really transmitted and utilized.

Phenomena peculiar to a Starting, or Stopping, or Varying Current.

There is a remarkable fact concerning electric currents of varying strength, which has been lately brought into prominence by the experimental skill of Prof. Hughes, viz. that a current does not start or stop equally and simultaneously at all points in the section of a conductor, but starts at the outside first. This fact is naturally more noticeable with thick wires than with thin, and it is especially marked in *iron* wires, for reasons which in Part III. will become apparent; but the general cause of it in ordinary copper wires can very easily be perceived in the light of the views of Prof. Poynting just mentioned.

For, remember that a current in a wire is not pushed along by a force applied at its end, so as to be driven over obstacles by its own momentum combined with a *vis a tergo*; but it is urged along at every point of its course by a force just sufficient to make it overcome the resistance there, and no more, the force being applied to it through the medium of the dielectric in which the wire is immersed. A lateral force it is which propels the electricity; and it naturally acts first on the outer layers of the wire or rod, only acting on the interior portions through the medium of the outside.

To illustrate this matter further, rotate a common tumbler of liquid steadily for some time and watch the liquid; dusting powder perhaps over it to make it more visible. You will see first the outer layer begin to participate in the motion, and then the next, and then the next, and so on, until at length the whole is in rotation. Stop the tumbler, and the liquid also begins gradually to stop by a converse process.

If the liquid sticks together pretty well, like treacle, the motion spreads very rapidly: this corresponds to a poor conductor. If the liquid be very mobile, the propagation of motion inward is slow: this corresponds to a very good conductor. If the liquid were perfectly nonviscous, it would correspond to a perfect conductor, and no motion would ever be communicated to it deeper than its extreme outer skin.

Think now of a long endless tube full of water, say the hollow circumference of a wheel, and spin it: the liquid is soon set in rotation, especially if the tube be narrow or the liquid viscous; but it is set in motion by a lateral not an end force, and its outer layers start first.

Just so is it with a current starting in a metal wire. If the wire be fine, or its substance badly conducting, it all starts nearly together; but if it be made pretty thick, and of well conducting substance, its outer layers may start appreciably sooner than the interior. And if it were infinitely conducting, no more than the outer skin would ever start at all.

In actual practice the time taken for all the electricity in an ordinary wire to get into motion is excessively short—something like the thousandth of a second—so that the only way to notice the effect is to start and reverse the current many times in succession.

If the hollow-rimmed wheel above spoken of were made to oscillate rapidly, it is easy to see that only the outer layers of water in it would be moved to and fro; the innermost water would remain stationary; and accordingly it would appear as if the tube contained much less water than it really does. The virtual bore of the pipe would, in fact, for many purposes be diminished. So is it also with electricity; the sectional area of a wire to a rapidly alternating current is virtually lessened so far as its conducting power is concerned; and accordingly its apparent resistance is *slightly higher for alternating than* for steady currents. The effect is however too small to notice in practice except with thick wires and very rapid alternations.

By splitting up the conductor into a bundle of insulated wires, thus affording the dielectric access to a considerable surface of conductor, the force is applied much more thoroughly, and so the effect spoken of is greatly lessened. The same thing is achieved by rolling out the conducting-rod into a flat thin bar. Making the conductor hollow instead of solid offers no particular advantage, because no energy travels *viâ* the hollow space, it still arrives only from the outside; *unless*, indeed, the return part of the circuit is taken along the axis of the hollow like a telegraph cable. In this last arrangement all the energy travels *viâ* the dielectric between the two conductors, and none travels outside at all. It will be perceived therefore that, as in static electricity, the term "outside" must be used with circumspection: it really means that side of a conductor which faces the opposite conductor across a certain thickness of dielectric.

We learn from all this that, whereas in the case of steady currents the sectional area and material of a conductor are all that need be attended to, the case is different when one has to deal with rapidly alternating currents, such as occur in a telephone, or, again, such as are apt to occur in a Leyden-jar discharge (see Part I., p. 560), or in lightning.

In all these cases it is well to make the conductor expose considerable surface to the propelling medium—the dielectric—else will great portions of it be useless.

Hence, a lightning-conductor should not be a round rod, but a flat strip, or a strand of wires, with the strands as well separated as convenient: and though I have not yet mentioned the special effect of iron, I may as well say here that iron is about 90,000 times worse than copper for the purpose of a lightning-conductor in respect of the phenomenon just described, seven times as bad on account of its inferior conducting power, and about twice as good as copper because of its higher melting-point and specific heat.

The Question of Electrical Momentum again.

We are now able to return to the important question whether an electric current has any momentum or not, as it would have if it were a flow of material liquid. Referring to Part I. (p. 533), a hint will be found that the laws of flow of a current in conductors—the shape of the stream-lines, in fact—are such as indicate no inertia, or else no friction. Now Ohm's law shows that at any rate *friction* is not absent from a current flowing through a metal; hence it would appear at first sight as if *inertia* must be absent.

The stream-lines bear upon the question in the following kind of way. If an obstacle is interposed in the path of a current of water, the motion of the water is unsymmetrical before and behind the obstacle. The stream-lines spread out as the water reaches the obstacle, and then curl round it, leaving a space full of eddies in its wake (Fig. 14).

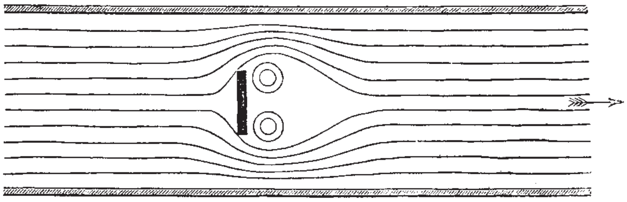

FIG. 14.—Stream-lines of water flowing through a pipe with an obstruction in it.

But if one puts an obstacle in the path of an electric current—say by cutting a slit in a conducting strip of tinfoil—the stream-lines on either side of it are quite symmetrical, thus—

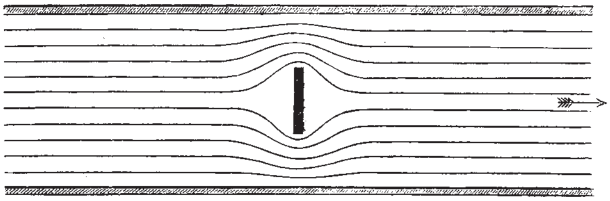

FIG. 15.—Electrical stream-lines past an obstacle.

And this is exactly what would be true for water also, if only it were devoid either of friction or of inertia, or of both.

Is not this fact conclusive, then? Does it not prove the absence of momentum in electricity?

Plainly the answer must depend on whether there is any other possible mode of accounting for this kind of flow. And there is.

For suppose that water, instead of being urged by something not located at or near the obstacle—instead of being left to its own impetus to curl round or shoot past as it pleases—suppose it were propelled by a force acting at every point of its journey, a force just able to drive it at any point against the friction existing at that point and no more; then the flow of water would take place according to the electrical stream-lines shown in Fig. 15.

An illustration of such a case is ready to hand. Take a spade-shaped piece of copper wire or sheet, heat it a little, and fix it in quiescent smoky air; looking along it through a magnifier in a strong light you will see the warmed air streaming past the metal according to the stream-lines of Fig. 15; and this just because the moving force has its location at the metal surface, and not in some region below it. (See Lord Rayleigh, NATURE, vol. xxviii. p. 139). One cannot indeed say that it is propelled at every point of its course, but it is propelled at the critical points where the special friction occurs, and this comes to sufficiently the same thing.

We learn, therefore, that stream-lines like Fig 15 prove one of three things, not one of two; and the three things are: (1) that the fluid has no friction; or (2) that it has no inertia; or (3) that it is propelled at every point of its course.

If any one of these is true of electricity, there is no need to assume either of the others in order to explain the actual manner of its flow. Now we have just seen that, according to Prof. Poynting's interpretation of Maxwell's theory, the third of the above is true—electricity is propelled at every point of its course; consequently, as said in Part I. (p. 533), the question of its inertia so far remains completely open.

Voltaic Battery.

Leaving this singular mode of regarding the subject for the present, to return to it perhaps after Part III., let us proceed to ask how it comes about that a common battery or a thermopile is able to produce a current.

If we allow ourselves to assume the existence of an unexplained chemical attraction between the atoms of different substances, an explanation of the action of an ordinary battery cell is easy. You have first the liquid containing, let us say, hydrogen and oxygen atoms, free or potentially free—that is, either actually dissociated or so frequently interchanging at random from molecule to molecule that the direction of their motion may be guided by a feeble directive force. Each of these atoms in the free state possesses a charge of electricity—the hydrogen all a certain amount of positive electricity, the oxygen twice that amount of negative. Into this liquid you then plunge a couple of metals which attract these atoms differently: for instance, zinc and copper, which both attract oxygen, but zinc more than copper; or, better, zinc and platinum, the latter of which hardly attracts it at all; or, better still, zinc and peroxide of lead, one of which attracts oxygen, the other hydrogen.

Immediately, the free oxygen atoms begin moving up to the zinc, the free hydrogen atoms to the other plate.

When one speaks of the plates attracting the atoms, it is not necessary to think of their exerting a force on all those in the liquid, distant and near: all that is necessary is to assume a force acting on those which come within what is called "molecular range" of its surface—a distance extremely minute, and believed to be about the ten-millionth part of a millimetre. If the zinc plate removes and combines with all the oxygen atoms which come within this range, they will be speedily replaced by others from the next more distant layer by diffusion, and these again by others, and so on. And thus there will be a gradual procession of oxygen atoms all through the liquid towards the zinc, the rate of the procession being regulated by the force acting, and by the rate of diffusion possible in the particular liquid used. All the atoms which reach the zinc neutralize a certain portion of its electricity by means of the positive charge they carry, and thus very soon it would become positively electrified enough to neutralize its attractive power on the similarly charged oxygen atoms, and everything would stop. But if a channel for the escape of its electricity be provided by leading a wire from it to the copper plate, the circuit is completed, the electricity streams back by the wire, and the procession goes steadily on. The electricity thus imparted to the copper, or platinum, neutralizes any repulsion it exerted on the negatively charged hydrogen atoms, and makes them in a similar way begin a procession towards it, deliver up their charges to it, combine with each other, and escape as gas.

Without going into all the niceties possible, this mode of thinking of the matter at least calls attention to some of the more salient features of a battery.

If, instead of two different plates, plates of the *same* metal be immersed, they will need to be oppositely electrified by some means before they are able to cause the two opposite processions, and so maintain a current in the liquid. This plainly corresponds to a voltameter.

Taking advantage of the known fact that the atoms are charged, Helmholtz avoids the necessity for postulating any chemical (non-electrical) force between zinc and oxygen, by imagining that all substances have a specific attraction for electricity itself, and that zinc exceeds copper and the other common metals in this respect.

He would thus think of the zinc attracting, not the oxygen itself, but its electric charge; and so would liken a battery cell still more completely to a voltameter. The polarization or opposition force acting at the hydrogen-evolving plate he would account for by the attraction of hydrogen for negative electricity, and the consequent repugnance of the hydrogen atoms to part with their charges.

Thermo-electric Pile.

A thermopile may be thought of in the following way, but in trying to understand the nature of these actions at present one must admit that some speculation and vagueness exist.

We have seen that when electricity is propelled through or among the molecules of a metal it experiences a certain resistance or opposition force which is exactly proportional to the speed of its motion. In other words, there is a connexion between matter and electricity in many respects analogous to fluid friction but varying accurately as the first power of the relative velocity. Hence, if an atom of matter be vibrating about a fixed point, it will tend to drive electricity to and fro with it; but if it be only one of a multitude, all quivering in different phases, they will none of them achieve any propulsion. This may be considered the state of an ordinary warm solid. But if from any cause a set of atoms could be made to move faster in one direction than in the reverse direction—to move forwards quickly and backwards slowly—then such an unsymmetrically-moving set *will* exert a propulsive tendency and tend to drive a current of electricity forwards, simply because the force exerted is proportional to the velocity, and so is greater on the forward journey than on the return.

Wherever conduction of heat is going on along a substance the atoms are in this condition. They are driven forward infinitesimally quicker, by the more rapidly moving atoms at the hot end, than they are driven back by the less rapidly moving atoms in front. And hence such a slope of temperature exerts a propulsive tendency: there is an electromotive force in a substance unequally heated.

This fact was discovered theoretically and verified experimentally by Sir William Thomson.

But not only is there such a force at a junction of a hot and cold substance, there is also a force at the junction of two substances of different kinds, even though the temperature be uniform. It is not quite so easy to explain how it now comes about that the atoms at this kind of junction are moving faster one way than the other; nevertheless, such a thing is not unlikely, considering the state of constraint and accommodation which must necessarily exist at the boundary surface of two different media. However it be caused, there is certainly an E.M.F. at such a junction.

Thus, then, in a simple circuit of two metals, with their junctions at different temperatures, there are altogether four electromotive forces—one in each metal, from hot to cold or *vice versâ*, and one at each junction; and the current which flows round such a circuit is propelled by the resultant of these four.

But the contact force at a junction is by no means confined to metals. It occurs between insulators also, and it is to it that the striking effects produced by all frictional electric machines are due.

By thus noticing that the connexion between matter and electricity, known as resistance and defined by Ohm's law, is competent to produce contact electromotive forces, we may perceive how it comes to pass that in good conductors such forces are so weak, while in insulators they are so strong. Electricity slips through the fingers of a metal as it were, and the driving force it can exert is very feeble; while an insulator gets a good grip and thrusts it along with violence.

The metals differ in their gripping power, and, roughly speaking, the best conductor makes the worst thermoelectric substance. A bad conductor, like antimony, or, still better, galena, or selenium, or tellurium, makes a far more effective thermo-electric element than a well-conducting metal. Not that specific resistance is all that has to be considered in the matter; there is also a specific relation between each metal and the two kinds of electricity. Thus, iron is a metal whose atoms have a better grip of positive than of negative electricity, and so a positive current gets propelled in iron from hot to cold. Copper, on the other hand, acts similarly on negative electricity, and it is a negative current which is driven from hot to cold in copper. And all the metals can be classed with one or other of these two, except perhaps lead, which appears to grip both equally, and so to exert no differential effect upon either.

Passage of Electricity through a Gas.

There remains to be said something about the way in which electricity can be conveyed by *gases*.

The first thing to notice is that there is no true conduction through either gases or vapours; in other words, a substance in this condition seems to behave as a perfect insulator—perhaps the only perfect insulator there is. Not even mercury vapour is found to conduct in the least. This shows that mere bombardment of molecules, such as is known to go on in gases, is not sufficient either to remove or to impart any electric charge.

The commonest way in which electricity makes its way through a gas, setting aside the mere mechanical conveyance by solid carrier, is that of disruptive discharge. Let us try and look into the manner of this a little more closely, if possible.

First of all, since locomotion is possible to the molecules of a gas the same as of any other fluid, it is natural to ask why electrolysis does not go on as in a liquid. Now, for electrolysis in a liquid two conditions seemed necessary: first, that the atoms or radicles in a molecule should be oppositely charged with electricity; second, that they should be in such a condition (whether by dissociation or otherwise) that interchanges of atoms from molecule to molecule, or, in some other way, a procession of atoms, could be directed in a given direction by a very feeble or infinitesimal force.

Since a gas does *not* act as an electrolyte, one of these conditions, or perhaps both, must fail. Either the atoms of a gas-molecule are not charged, which is a plausible hypothesis for elementary gases, or else the atoms belonging to a gas-molecule remain individually belonging to it, and are not readily passed on from one to another.

When one says that a gas does not act as a common electrolyte, the experimental grounds of the statement are that a finite electrostatic stress certainly is possible in its interior—a stress of very considerable amount; and when this stress does overstep the mark and cause the electrode to yield, the yielding is evidently not a quiet and steady glide or procession, but a violent breaking down and collapse, due to insufficient tenacity of something. One may therefore picture the molecules of a gas, between two opposite electrodes or discharge terminals maintained at some great difference of potential, as arranged in a set of parallel chains from one to the other, and strained nearly up to the verge of being torn asunder. In making this picture one need not suppose any fixture of individual molecules: there may be a wind blowing between the plates; but all molecules as they come into the field must experience the stress, and be relieved as they pass out.

If the applied slope of potential overstep a certain limit, fixed by observation at something like 33,000 volts per linear centimetre for common air, the molecules give way, the atoms with their charges rush across to the plates, and discharge has occurred. The number of atoms thus torn free and made able to convey a charge by locomotion is so great that there has never been found any difficulty in conveying any amount of electricity by their means. In other words, *during* discharge the gas becomes a conductor, and, being a conductor by reason of locomotion of atoms, it may be called an electrolytic conductor.

But whether the charge then possessed by each carrier atom intrinsically belonged to it all the time, or whether it was conferred upon the components of the molecules during the strain and the disruption, is a point not yet decided.

What is called "the dielectric strength" of a gas—that is, the strain it can bear without suffering disruption and becoming for the instant a conductor—depends partly on the nature of the gas, and very largely on its pressure. Roughly, one may say that a gas at high pressure is very strong, a gas, at low pressure very weak. An ordinary electrolyte might be called a dielectric of zero strength.

One reason why pressure affects the dielectric tenacity of a gas readily occurs to one: it is certainly not the only one, but it can hardly help being at least partially a *vera causa;* and that is, the fact that in a rare gas there are fewer molecules between the plates to share the strain between them.

Thus if 40,000 volts per centimetre break down ordinary air, 40 volts per centimetre ought to be enough to effect discharge through air at a pressure of about ¾ millimetre of mercury; and at a pressure of 50 atmospheres 2,000,000 volts per centimetre should be needed.[1]

A Current regarded as a Moving Charge.

To review the ground we have covered so far. We first tried to get some conception of the nature of electrostatic charge, and the function of a dielectric medium in static electricity. We next proceeded to see how far the phenomena of current electricity could be explained by reference to electrostatics. For a current, being merely electricity in locomotion, need consist of nothing but a charged body borne rapidly along.

Charge a sphere with either positive or negative electricity, and throw it in some direction: this constitutes a positive or a negative current in that direction. There is nothing necessarily more occult than that. And a continuous current between two bodies may be kept up by having a lot of pith balls, or dust particles, oscillating from one to the other and so carrying positive electricity one way, and negative the other way. But such carriers, as they pass each other with their opposite charges, would be very apt to cling together and combine. They might be torn asunder again electrically, or they might be knocked asunder by collision with others. Unless they were one or other, the current would shortly have to cease, and nothing but a polarized medium would result.

Instead of pith balls, picture charged atoms as so acting, and we have a rough image of what is going on in an electrolyte on the one hand, and a dielectric on the other. The behaviour of metals and solid conductors is more obscure. Locomotive carriage is not to be thought of in them; but, inasmuch as no new phenomenon appears in their case, it is natural to try and picture the process as one not wholly dissimilar; and this is what in one place we tried to do; with, however, but poor success.

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[1] It is true that tension per unit area, or energy per unit volume, is proportional to the *square* of the potential-slope, and I attach no special importance to the simple proportion assumed in the text. There is a great deal more to be said on these subjects, but this is scarcely the proper place to say it.

I have said that an electric current need be nothing more occult than is a charged sphere moving rapidly; and a good deal has been made out concerning currents by minutely discussing all that happens in such a case. But, even so, the problem is far from being a simple one. One has to consider not only the obviously moving charge, but also the opposite induced charge tied to it by lines of force (or tubes of induction, as they are sometimes called), and we have this whole complicated system in motion. And the effect of this motion is to set up a new phenomenon in the medium altogether—a spinning kind of motion that would not naturally have been expected; whereby two similarly charged spheres in motion repel one another less than when stationary, and may even begin to attract, if moving fast enough; whereby also a relation arises between electricity and magnetism, and the moving charged body deflects a compass needle. Of which more in the next Part. OLIVER J. LODGE.

(*To be continued.*)

THE TWEEDDALE COLLECTION.

THE great collection of birds formed by the late Marquess of Tweeddale has now safely arrived in London, and has been deposited in the Natural History Museum at South Kensington. It is sufficient to say that it equals in extent the valuable donation of American birds presented by Mr. Osbert Salvin and Mr. F. Du Cane Godman, numbering about 27,000 specimens; and though inferior in number of individual skins to the great Hume collection, which reached the phenomenal number of 63,000 specimens, it is not inferior in interest to either of these wonderful collections. Mr. Hume thoroughly worked the territory of the British Asian Empire from Scinde to Assam and Manipur, from Khatmandu to Ceylon, and from Tenasserim to Singapore; but to the eastward of these countries the work had been continued by other naturalists, and the results of their labours are largely represented in the Tweeddale collection, which now forms part of the British Museum.

On the death of the late Marquess, his entire collection and library were bequeathed by him to his nephew, Capt. R. G. Wardlaw Ramsay, of Whitehill, a naturalist of high promise and performance; and in the moment of satisfaction at receiving his magnificent donation one cannot help feeling great regret that the many cares and duties incident upon his succession to the family estates at Whitehill have temporarily deprived him of the leisure necessary for the working out of the great collection left to him by his uncle. The facilities for ornithological study, however, at the Natural History Museum, are now rapidly becoming so perfect that one may reasonably hope that he will, in common with all ornithologists, be able to work in that institution with the same comfort as in his own museum in Scotland. If in future years the student of birds finds that at South Kensington the work he loves can be done more expeditiously and with command of a larger series of specimens than in any other Museum in the world, his gratitude will be largely due to the four naturalists we have mentioned—Mr. Allan Hume, Messrs. O. Salvin and F. D. Godman, and Capt. Wardlaw Ramsay—for the unexampled generosity which has led them to present to the British nation the wonderful collections which will make our Ornithological Museum famous for all time.

Many naturalists who read this article will remember how, twelve years ago, the entire collection of bird-skins in the British Museum was contained in a few book-cases in a dingy cellar at Bloomsbury, where all the skins were kept in wooden boxes—a barbarous method, which was not only clumsy, but actually harmful to the specimens themselves. The development of the collection since that era is one which any English naturalist may consider with pride. Not only is the invaluable series of skins in the British Museum now well cared for and properly housed, but the *raison d'être* of the large collections in private hands has been removed. It is admitted on all sides that had the facilities of study in the old days been such as they now are in the Natural History Museum, there would have been no need for ornithologists to devote their private means to the formation of the collections which have, however, now become the foundation of the greatest Ornithological Museum in the whole world.

The three great collections which have enriched the British Museum during the last two years have each been, in their way, of supreme importance for zoological science. The Hume collection was a perfect marvel in the way of complete series of specimens. Not only are the various plumages of the Indian birds exemplified in a manner hitherto unheard of, but even the geographical ranges of most of the species are illustrated in a perfect way by the series of specimens contained in the collection. The Salvin-Godman donation consisted of American birds, and added hundreds of species to the British Museum which were desiderata to that collection. Though not so rich in series of various plumages as the Hume collection, the number of gaps in the quota of American birds which their donation filled was simply enormous, and from being one of the most backward in regard to its neotropical collection of birds, the British Museum is now one of the foremost as regards the value of its American series.

The Tweeddale collection "takes up the running," so to speak, where Mr. Hume left off, and it must not be supposed that the donation now made by Capt. Wardlaw Ramsay is merely the collection of skins left to him by his uncle. To imagine this would be but a poor appreciation of the energy which has led him during the last few years to develop and greatly increase the collection by the addition of a large number of birds obtained during his military career in the East, and by hundreds of other valuable specimens acquired since his uncle's death. Thus the skins from the Kurrum Valley in Afghanistan, and from the Karen Hills in Burmah, obtained by Capt. Ramsay himself, are supplementary additions of the highest value to the Hume collection, inasmuch as Mr. Hume never had correspondents in these parts, and the specimens from the Andamans and Nicobars are also of great importance; but of course the interest of the Tweeddale collection centres round the expedition to the Philippine Archipelago made by Mr. Alfred Everett for the late Marquess. Mr. Everett visited several islands on which no zoologist had previously trod, and as a natural result he discovered some beautiful new species of birds which are still unrepresented in any other collection but that of Capt. Ramsay. Altogether Mr. Everett furnished material for twelve important memoirs by the Marquess of Tweeddale, and the number of Philippine types now presented to the British Museum adds immensely to the wealth of the donation. Lord Tweeddale was also greatly interested in an obscure family of birds—the Drongos, or Crow-shrikes (*Dicruridæ*)—and possessed a wonderful collection of these birds, although it may be stated that there is scarcely a family of Oriental birds which is not strongly and completely represented in the collection.

Ornithologists will understand the nature of this noble gift of Capt. Ramsay when they learn that in addition to the collection of birds he has also presented the whole of the splendid Tweeddale library (nearly 3000 volumes) to the British Museum, to be placed in the Bird-Room, alongside of the collection of skins, for the benefit of students of ornithology. The Tweeddale library is one of the best in the world, containing many rare volumes which